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Corrosion Behavior of Stainless Steels in Neutral and Acidified Sodium Chloride Solutions by Electrochemical Impedance Spectroscopy

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OBJECTIVE

The objective of this work was to evaluate the corrosion performance of three alloys by Electrochemical Impedance Spectroscopy (EIS) and to compare the results with those obtained during a two-year atmospheric exposure study.¹ Three alloys: AL6XN (UNS N08367), 254SMO (UNS S32154), and 304L (UNS S30403) were included in the study. 304L was included as a control. The alloys were tested in three electrolyte solutions which consisted of neutral 3.55% NaCl, 3.55% NaCl in 0.1N HCl, and 3.55% NaCl in 1.0N HCl. These conditions were expected to be less severe, similar, and more severe respectively than the conditions at NASA's Kennedy Space Center launch pads.

SELECTED RESULTS

The impedance data for the alloys in the three electrolyte solutions were gathered after the open circuit potential (ocp) had stabilized. Nyquist as well as Bode plots of the data were obtained. It was determined that the response of the alloys with immersion time was more evident in the Nyquist plots. The Nyquist plots exhibited only one capacitive contribution represented by a semicircle. An equivalent circuit consisting of a parallel RC arrangement in series with the solution resistance, R_s , was used to simulate the data. The polarization resistance is a direct measure of the corrosion resistance in the solution at open circuit condition since the rate of corrosion is inversely proportional to the polarization resistance.

The three alloys showed a similar behavior in the neutral 3.55% NaCl solution. The Nyquist plots showed that there is an increase in the corrosion resistance of the three alloys during the first 24 hours of immersion that remains fairly unchanged thereafter. When HCl is present in the electrolyte solution, the initial increase in the corrosion resistance of the material is followed by a gradual decrease except for 304L. This alloy exhibited a significant decrease of its corrosion resistance. Fig. 1 shows that the behavior of 304L, when the concentration of the acid in the electrolyte is increased to 1.0N, is significantly different from the other alloys. There is a significant decrease in its corrosion resistance starting at the initial immersion time.

R_p values obtained from the Nyquist plots were plotted as a function of immersion time for the three alloys in the three electrolyte solutions. These plots revealed that there is no significant difference in the R_p values for the alloys in neutral 3.55% NaCl. When the concentration of HCl in the solution is increased to 0.1N,

AL6XN at all immersion times. Data collection for the 304L SS samples was terminated when a color change in the electrolyte solution was observed and the data became very noisy. The changes in the R_p values with immersion time were consistent with those obtained previously from linear polarization data.² It was noticed that, when the concentration of the acid in the 3.55% NaCl solution was 0.1N, the ocp values for 304L were different from those of AL6XN and 254SMO from the beginning of immersion while the R_p values for the three alloys were not significantly different until the immersion time reached 72 hours.

Laboratory results were compared to those from a two-year atmospheric exposure study under conditions designed to simulate those present at NASA's Kennedy Space Center launch pads. The comparison revealed that one year of atmospheric exposure in a natural marine environment is more aggressive than 408 hours of immersion in a neutral 3.55% NaCl electrolyte solution.

CONCLUSIONS

The higher-alloyed 254SMO and AL6XN exhibited a significantly higher resistance to corrosion than 304L as the concentration of hydrochloric acid in the 3.55% NaCl solution increased. The polarization resistance values obtained from EIS measurements were consistent with those from linear polarization measurements, and were indicative of the actual long-term corrosion performance of the alloys during the atmospheric exposure study.

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